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Exchange rates, commodities and the implications of volatility in a small open economy world

Rebecca Driver

and

Stephen Millard[*]

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Abstract

For most OECD countries a significant fraction of both imports and exports is made up of commodities, which are used as inputs into manufacturing. In contrast most new open economy models tend to assume that trade takes place solely in manufactured goods. One exception to this is Driver (2002) which takes the well-known Obstfeld and Rogoff (1995) *Redux* model and shows that the introduction of trade in commodities, as well as manufactured goods, can significantly alter the response to monetary shocks. This paper extends these results to look at the volatility of commodity prices, the link to exchange rate volatility and whether there are any implications for monetary policy. To do this we use a small-open-economy version of the Driver (2002) model. We also examine the implications of different assumptions about exchange rate pass-through, namely whether the conclusions change if firms trading in manufactured goods use a local currency pricing rule rather than producer currency pricing (as is assumed in the *Redux* model). Finally, we offer some thoughts as to whether or not monetary policy should respond to commodity price movements and whether or not the answer to this question depends on the persistence and volatility of such shocks.

Key Words: Commodities, Exchange Rates, Monetary Policy

JEL classifications: E52, F32, F41

[*] Bank of England, Threadneedle Street, London, EC2R 8AH. The views expressed in the paper are those of the authors and do not necessarily reflect those of the Bank of England or its Monetary Policy Committee.

1 Introduction and Overview

For an economy such as the United Kingdom that both imports and exports commodities, it is clear that movements in the supply and price of commodities are likely to have macroeconomic implications. Given this, it would seem important to know both how shocks to commodity supply or commodity prices affect key macroeconomic variables like output and inflation and how, indeed whether, policy should respond to such shocks. This is particularly important because countries cannot choose their commodity endowments.[1] This paper aims to look at the volatility of commodity prices, the link to exchange rate volatility and whether there are any implications for monetary policy. One of the key factors determining the outcome of this analysis will be the behaviour of traded manufactured goods prices following both exchange rate and commodity price changes.

One of the big debates in the new open economy macroeconomic literature is how firms respond to exchange rate changes. (See, for example, Obstfeld (2002).) At one end of the spectrum it is assumed that firms set prices in their domestic currency (producer currency pricing) and that firms fully pass through any changes in the exchange rate into the prices they charge in foreign markets. Under the alternative assumption of local currency pricing, it is assumed that prices are set in the buyer's currency and, in the short run at least, changes in exchange rates will have no impact on these prices. Local currency pricing may therefore be one explanation for the so-called 'exchange rate disconnect' puzzle: that is, that large movements in the exchange rate have not been associated with large movements in import and export prices and the consumer price index, as might be suggested by a standard model. See for example Devereux and Engel (2002).[2]

The two extremes of producer currency and local currency pricing suggest very different transmission mechanisms from the exchange rate to the rest of the economy, with very different implications for the risks facing firms. For example a firm that can lock a foreign buyer into a contract involving a given quantity of goods at a price

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[1] Commodity endowments may, of course, influence the choice of manufacturing processes. A major source of debate in the 1970s and 1980s when North Sea Oil came on stream was what impact this would have on industrial structure. Many economists were worried about the consequences of reduced demand for UK manufactured goods abroad following the oil-induced appreciation of the exchange rate: the so-called 'Dutch Disease'. See for example Neary (1988) and Fender (1985). There was also the question of whether the Government should react to the discoveries by investing the oil revenues today against a future without oil. For simplicity, however, this paper does not consider whether commodity price movements cause sectoral shifts within and between economies.

set in the firm's own currency is largely insulated from exchange rate changes. However it may not be in the firm's interest to attempt to negotiate this type of contract if its rivals are offering the buyer the opportunity buy the goods at a price set in the buyer's currency, allowing the purchaser to minimise exchange rate risk.

Exactly how the choice of currency denomination in contracts is determined is a complex issue. Bacchetta and van Wincoop (2002), for example, present a model where currency denomination is determined by four main factors: the extent of differentiation of goods within an industry; the market share of an exporting country's firms; the overall size of the exporting country; and the cyclicality of real wages. Of these factors Bacchetta and van Wincoop (2002) show that the first two are the most important. The higher the market share of their domestic economy and the greater the degree of product differentiation then the more likely exporting firms are to price in their own currency, so increasing pass-through. The last two factors are linked. For a small country, where imports make up a large proportion of consumption, a change in the exchange rate potentially affects costs (through nominal wages) as well as revenues on foreign sales. In such circumstances it becomes more attractive for firms in the small country to price in the importer's currency.

Bacchetta and van Wincoop (2002) do not consider the interaction between monetary policy and the choice of pass-through. Devereux *et al* (2002) suggest that pass-through will be linked to the degree of exchange rate volatility, with pass-through falling as volatility increases, and that both domestic and foreign firms will choose to set prices in the currency where the volatility of money growth (or monetary policy shocks) is lowest. Corsetti and Pesenti (2002) present a model that suggests that monetary union becomes optimal when local currency pricing dominates. Empirically both Taylor (2000) and Gagnon and Ihrig (2001) have linked the recent reduction in exchange rate pass-through to changes in monetary regimes.[3]

One factor that has not been considered within models explaining the choice of firms' pricing policies, however, is the impact of trade in commodities on the decisions of both firms and monetary policy makers. This is clearly important because raw materials are an important input into production. (Materials account for around 50% of inputs into production in the United Kingdom.) In addition, many economies,

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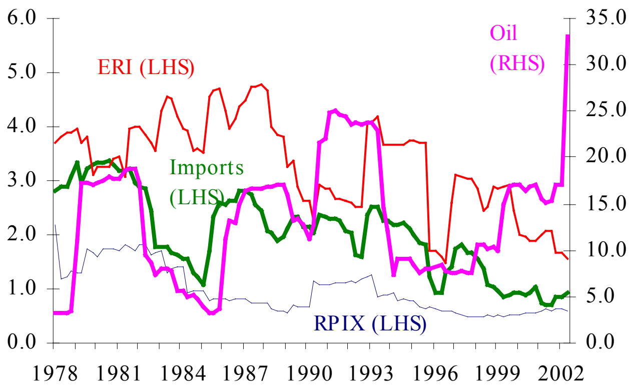
[2] Devereux and Engel (2002) suggest that this can be explained by a combination of imperfect capital markets, producer currency pricing and a volatile exchange rate risk premium.

[3] One important caveat is that while pass-through into consumer prices and GDP deflators appears to have fallen in recent years, exchange rate pass-through into import prices is less affected by regime changes. For import prices, changes in the aggregate pass-through appear to be explained better by shifts in the industry composition of imports, see Campa and Goldberg (2002).

including OECD economies, have considerable endowments of commodities with the result that they both import and export commodities. (Indeed, over 15% of both UK imports and exports are in commodities.) The results in Driver (2002) suggest that introducing trade in commodities can be important, particularly for the transmission of monetary policy, because of the wealth effects associated with changes in the exchange rate. The analysis in Driver (2002) concentrates on the implications of permanent shocks. However, one of the stylised facts of commodities is that their prices tend to be more volatile than those of manufactured goods and that if anything this volatility has increased following the breakdown of the Bretton Woods fixed exchange rate system, see for example Cashin and McDermott (2001). If more volatile commodity prices raise consumption volatility, then the associated increases in risk premia might lead to lower consumption and investment. An important question is therefore to what extent economies can and should insulate themselves from such changes.

Chart 1. Twelve quarter standard deviation



The volatility of commodity prices is particularly striking when compared to recent declines in inflation volatility. Chart 1 shows the standard deviation of quarterly percentage changes in four series for the UK: oil prices, the nominal effective exchange rate (ERI), import prices and the retail price index (RPIX). For each case a single observation represents the standard deviation of the changes over the preceding twelve quarters and can be interpreted as an indication of volatility over the immediate past. It is easy to see from Chart 1 that the volatility of both RPIX and import price inflation has been falling since the early 1990s. In contrast there has been no such decline in the volatility of oil prices. Indeed, the analysis in Cashin and McDermott (2001) suggests that there has been no decline in the volatility of a broad range of commodity prices. With the exception of the very recent past there is little sign that the volatility of the sterling effective exchange rate has declined substantially. This suggests that the transmission of oil price and exchange rate volatility into inflation volatility may have changed – in which case monetary policy makers need to understand how and why.

Previous papers such as Bacchetta and van Wincoop (2003), Kara and Nelson (2002) and McCallum and Nelson (2000) have looked at the implications of imported manufactured inputs that are then combined with retail services to produce the finished goods. McCallum and Nelson (2000) suggest that if imports are predominantly inputs to production rather than final goods, then volatility in the exchange rate will not transmit into volatility in the consumer price index. Given that manufactured goods prices appear inherently less volatile than commodity prices it is interesting to look at how the transmission mechanism changes when raw materials are used.

This paper aims to look at the volatility of commodity prices, the links to exchange rates and whether there are any implications of this for monetary policy. For example should monetary policy respond to commodity price movements and does it matter whether these shocks are permanent or temporary, or whether the shocks are to domestically or foreign produced commodities? The paper therefore provides a framework in which all countries receive an endowment of commodities and where both domestic and foreign commodities are needed to produce manufactured goods. We use a version of the model in Driver (2002) in which we allow for the possibility of local currency as well as producer currency pricing, which, in turn, may provide some insight into the exchange rate disconnect puzzle (why trade prices do not respond to exchange rate movements). We examine a small open economy version of the model as the implications of commodity price movements are likely to depend on the size of the economy and many commodity importers and exporters, including the United Kingdom, are more closely described as small. In the small open economy case, commodity price volatility will be exogenous: this represents a substantial simplification in terms of solving the model while not detracting from the main issue we wish to consider.

Previous empirical work such as Chen and Rogoff (2002) and Cashin *et al* (2002) suggests that movements in exchange rates and commodity prices may be linked for commodity exporters. We suggest that the volatilities of export and import prices are partly driven by the volatility of commodity prices whereas exchange rate volatility is independent of commodity price volatility. If this is true, it will, again, be the case that exchange rate volatility is disconnected from volatility in import, export and consumer prices. Given the results of this analysis, we can suggest whether or not monetary policy should respond to commodity price movements and whether or not the answer to this question depends on the degree of persistence of such shocks.

The structure of the paper is as follows. In section 2, we develop the model and, in section 3, we examine the effects of commodity price shocks in our model. Section 4 discusses the extent to which commodity price volatility is related to volatility in the exchange rate and import, export and consumer prices. Section 5 discusses the implications of our results for monetary policy and section 6 concludes.

2 The Model

In this paper, we develop a small open economy model based on the two-country model developed in Driver (2002). We consider two different pricing rules: one in which firms price in their own currency and one in which they price in local currency. In what follows, we briefly sketch the problems facing consumers and firms before going on to discuss how we calibrate the model using UK data.

2.1 Consumers

The representative consumer either consumes or invests in financial assets in order to maximise his utility subject to an asset accumulation constraint. He values consumption of a variety of final goods, leisure and holdings of real money balances. If c^D denotes the real consumption index, M^D end-of period money holdings and his total hours worked are denoted by h^D then the consumer's problem will be to maximise:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\ln(c_t^D) + \chi \ln\left(\frac{M_t^D}{P_t^D}\right) - \psi h_t^D \right) \quad \textbf{(1)}$$

subject to a budget constraint. We assume that the representative consumer can invest in foreign nominal bonds, B^F, and borrow by issuing domestic nominal bonds B^D. Following Driver (2002), we assume that each period the representative domestic consumer receives an endowment of a commodity, e_1, which he sells on the world spot market at a foreign-currency price of P_1. We assume that the rest of the world is endowed with this commodity and also with another commodity, e_2, that is sold on the world spot market at a foreign currency price of P_2. We use foreign currency for pricing both commodities to reflect the fact that commodities tend to be priced in dollars rather than sterling. We assume that the consumer is unable to store commodities and so, each period, he will sell his entire endowment.[4] Hence, the domestic consumer's budget constraint will be:

$$M_t^D - B_t^D + B_t^F s_t = M_{t-1}^D + T_t^D + D_t^D - B_{t-1}^D\left(1+i_{t-1}^D\right) + B_{t-1}^F s_t (1+i_{t-1}^F) \\ + P_t^D w_t^D h_t^D + P_{1,t} s_t e_{1,t} - P_t^D c_t^D \qquad \textbf{(2)}$$

where w^D is the real wage, s is the exchange rate (units of domestic currency per unit of foreign currency), P^{D} is the domestic consumption based price index, i^{D} is the domestic nominal interest rate, i^{F} is the foreign nominal interest rate, T^{D} is a nominal transfer from the government and D^{D} is dividends from domestic firms (assumed to be owned by the representative consumer). We assume that the consumer takes real wages, the government transfer, dividends, all prices and nominal interest rates as given.

2.2 Firms (Producer Currency Pricing Case)

We assume that the representative domestic firm operates in a monopolistically competitive world market. Hence, the demand curve for the domestic firm is assumed to take the Dixit-Stiglitz form:

$$y_t^D = \left(\frac{P_{D,t}^D}{P_t^D}\right)^{-\theta} y_t \qquad \textbf{(3)}$$

where y^{D} is the output of the domestic firm, $P_{\mathrm{D}}^{\mathrm{D}}$ is the price it sets in domestic currency, y is world demand (assumed to be exogenous) and θ is the elasticity of substitution between goods. The assumption that consumers love variety of goods, so that the demand curve takes the Dixit-Stiglitz form, implies that the domestic price level in the producer-currency-pricing case will be given by:

$$P_t^D = \left[\int_0^n P_{D,t}^D(z)^{1-\theta}\,dz + \int_n^1 \left(s_t P_{F,t}^F(z)\right)^{1-\theta} dz\right]^{\frac{1}{1-\theta}} \qquad \textbf{(4)}$$

where $P_{\mathrm{F}}^{\mathrm{F}}$ is the price set by foreign firms in foreign currency, z is used to index the individual firms and n is proportion of firms in the domestic economy. Therefore n also represents the share of the composite good produced domestically.

[4]Introducing the option of storing commodities creates non-linearities in agents' decision rules and so is not easily handled using standard techniques. However, we aim to return to the issue of storage in future work.

The producer's problem will be to maximise profits in each period subject to a production function and its demand curve, given by equation **(3)**. Following Driver (2002), we assume that output is produced by combining inputs of labour and the two commodities, so that the production function is:

$$y_t^D = A_t^D \left(h_t^D\right)^{1-\alpha} \left(\eta\left(e_{1,t}^D\right)^{1-\nu} + (1-\eta)\left(e_{2,t}^D\right)^{1-\nu}\right)^{\frac{\alpha}{1-\nu}} \qquad \textbf{(5)}$$

where e_1^D is domestic demand for the domestic commodity, e_2^D is domestic demand for the foreign commodity, A^D is the level of total factor productivity of the domestic firms, α is the share of commodities in output and the elasticity of substitution between commodities is given by 1/ν. Profits are therefore given by:

$$P_{D,t}^D y_t^D - P_{1,t} s_t e_{1,t}^D - P_{2,t} s_t e_{2,t}^D - w_t^D P_t^D h_t^D \qquad \textbf{(6)}$$

When the nominal exchange rate appreciates in response to a shock therefore, there will be a reduction in the firm's costs, as the domestic price of the commodity inputs will fall, but also a fall in demand following the change to relative prices (see equations **(3)** and **(4)**). The overall impact on profits therefore will be ambiguous.

We assume that the prices of final goods are 'sticky'. To achieve this, we assume that the representative domestic firm has to set its price based on information available one period in advance. Given its information, it will set its price in domestic currency equal to that expected to clear the market for its goods. Once it has set its price, the shocks are realised. We think of one period of this model as being one year.

With producer currency pricing, prices are set in the producers' currency. Therefore when the exchange rate changes in response to a shock, the firm fully passes the exchange rate change through into the prices they charge in the overseas market. As such the law of one price always holds and exchange rate changes have an immediate impact on price levels. The finding that the law of one price holds relies on the assumption that the elasticity of demand faced by the firms is the same in all markets. If the elasticities of demand differ across markets then the firms will charge location specific prices, so that the law of one price will never hold as long as markets are separated and consumers cannot arbitrage across markets.[5] However, under producer currency pricing the firms would still pass all of the exchange rate change through into the prices they charge abroad. (See, for example, the discussion in Obstfeld (2002).) For simplicity we assume that the elasticities of demand are the same across

[5] See Benigno and Thoenissen (2002) for a discussion of other potential reasons for the law of one price to fail.

markets. Finally, we can note that since the law of one price applies for all goods, then purchasing power parity will hold in this version of the model.

2.3 Firms (Local Currency Pricing Case)

In this case, the representative firm set the price for each market in the currency of the local consumer. Hence, when prices are sticky there will be no impact from an exchange rate change on the price of final goods in either market as there will be no exchange rate pass-through in the short run and the law of one price will fail. This implies that the existence of local currency pricing is one option for explaining the 'exchange rate disconnect' puzzle whereby real and nominal exchange rates are highly correlated. (See, for example, Devereux and Engel (2002).)

If it prices in local currency then the demand curve for the domestic firm will be:

$$y_t^D = \left(\frac{P_{D,t}^F}{P_t^F} \right)^{-\theta} y_t \qquad \textbf{(7)}$$

where P^F is the foreign price level, P_D^F is the price the domestic firm sets in foreign currency for the goods it sells in the foreign market and y is world demand and is exogenous.

So, the firm's problem can now be written as:

Maximise
$$P_{D,t}^F s_t \left(\frac{P_{D,t}^F}{P_t^F} \right)^{-\theta} y_t - P_{1,t} s_t e_{1,t}^D - P_{2,t} s_t e_{2,t}^D - w_t^D P_t^D h_t^D \qquad \textbf{(8)}$$

Subject to
$$y_t^D = A_t^D \left(h_t^D\right)^{1-\alpha} \left(\eta \left(e_{1,t}^D\right)^{1-\nu} + (1-\eta)\left(e_{2,t}^D\right)^{1-\nu} \right)^{\frac{\alpha}{1-\nu}} \qquad \textbf{(9)}$$

Changes in the nominal exchange rate in response to shocks will therefore again influence both the revenues that firm receives as well as the costs associated with the commodity inputs. The impact of an exchange rate appreciation on profits will again be ambiguous but, unlike the producer currency pricing case, the change in the exchange rate will have a direct impact on revenues, through the domestic currency price, but no impact on relative demand.

For simplicity equation **(7)** does not differentiate between the elasticities of demand, θ, in the domestic and foreign markets, as the domestic market is seen to be small. However, these elasticities do not have to differ for local currency pricing to take place. If the elasticities are the same then the prices set by firms in the two markets in steady state will be the same, so that the law of one price will hold in steady state. However in the short run with sticky prices the lack of exchange rate pass-through implies that the law of one price will fail.[6] Again, we assume that the firm has to set its price in each market based on information available at the end of the previous period. These prices will then be sticky for one period.

2.4 Government and Monetary Policy

Monetary policy in this model is operated via changes in the money stock. The government transfers any seignorage revenue back to the consumer as a lump sum. Hence:

$$M_t^D - M_{t-1}^D = T_t^D \tag{10}$$

2.5 Imports, exports and the balance of payments

Since we are emphasising the importance of export and import prices in the transmission of commodity price volatility, it is worth considering the external sector of the model explicitly. We can combine the consumer's budget constraint, equation **(2)**, with dividends paid out by firms, which by definition are given by profits, equation **(8)**, and the government's budget constraint, equation **(10)**, to obtain the balance of payments equation. Under the assumption of local currency pricing this will be:

$$\begin{aligned} s_t\left(B_t^F - B_{t-1}^F\right) - \left(B_t^D - B_{t-1}^D\right) = \left(i_{t-1}^F B_{t-1}^F s_t - i_{t-1}^D B_{t-1}^D\right) + \left(P_1 s_t \left(e_{1,t} - e_{1,t}^D\right) + P_{D,t}^F s_t \left(\frac{P_{D,t}^F}{P_t^F}\right)^{-\theta^F} y_t \right) \\ - \left(P_2 s_t e_{2,t}^D + P_{F,t}^D \left(\frac{P_{F,t}^D}{P_t^D}\right)^{-\theta^D} c_t^D \right) \end{aligned} \tag{11}$$

where P_F^D is the price the foreign firm charges in domestic currency. For clarity the elasticity of demand at home and abroad are allowed to differ, although in practice it is assumed that these are the same. The left-hand side of this equation is the capital account for the domestic economy. The right-hand side of this equation is the current account. The first term on the right hand side of this equation represents net flows of interest, profits and dividends (IPD). (In this model we have assumed that all profits and dividends go to residents in the same country as the firms, so IPD flows will only

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[6] If we assume that domestic and foreign markets are segmented and that the elasticities of demand differ in each of these two markets, then firms will always want to set a different price in each market.

consist of interest payments.) The second term on the right hand side of this equation is exports, which consist of commodity exports and goods exports. Finally, the third term on the right hand side of the equation is imports, again consisting of both commodity and goods imports. The 'balance of trade' is defined as exports less imports.

Import and export prices will depend not only on the prices of manufactured goods, but also the prices of commodities. Thus, the effect of movements in the exchange rate on import prices will depend on the extent of any movements in commodity prices. In the absence of changes in commodity prices themselves, the observed exchange rate pass-through into aggregate import prices in the domestic economy will depend on the proportion of commodities in imports, with pass-through rising as the share of commodities increases.[7] However, there will be no short run pass-through from exchange rates into consumer prices as manufactured goods prices are sticky in local currency.[8] The bottom line is that, in our model, the exchange rate has been partially 'disconnected' from import prices and fully 'disconnected' from consumer prices in the short run. Long-run pass-through will be higher, however, if the source of the shock to the exchange rate persists. In the producer currency pricing case there will be full pass-through of exchange rate changes into import prices.

2.6 Exogenous Variables

We assume that the exogenous variables in the producer-currency-pricing version of the small open economy model follow the following processes: [9]

As a result the law of one price will never hold.

[7] Commodity prices are quoted in foreign currency. For this reason there will be no change in the observed foreign import price of commodities when the exchange rate changes. However, as the domestic currency price of commodities will have changed, pass-through will be full when measured relative to that.

[8] See for example Campa and Goldberg (2002) for a sectoral story to explain shifts in observed aggregate exchange rate pass-through into import prices.

[9] Our model suffers from the problem – common to many small open economy models – that steady-state foreign bond holdings are indeterminate in our model. As a result, temporary shocks will shift the steady state of the model through their effects on wealth. This means that the equilibrium around which log-linear approximations are taken is moving over time. This problem can be addressed in a number of ways. One approach is to make assumptions about the form of the utility function or the way in which consumption is aggregated. Another approach is to impose a global equilibrium condition on asset holdings and restrict the trade balance to be zero in all periods, but this seems too restrictive. So instead we assume that these steady-state effects arising from changes in the level of foreign bond holdings are small enough to be ignored: this enables us to substitute foreign bond holdings out of the model and concentrate on the movements of the other variables, as in Batini, Harrison and Millard (2001). However, it does mean that changes in the domestic economy's

$$\ln\left(M_t^D\right) = \rho_M \ln\left(M_{t-1}^D\right) + \varepsilon_{M,t} \quad \textbf{(12)}$$

$$\ln\left(A_t^D\right) = \rho_A \ln\left(A_{t-1}^D\right) + \varepsilon_{A,t} \quad \textbf{(13)}$$

$$\ln\left(P_{1,t}\right) = \rho_1 \ln\left(P_{1,t-1}\right) + \varepsilon_{1,t} \quad \textbf{(14)}$$

$$\ln\left(P_{2,t}\right) = \rho_2 \ln\left(P_{2,t-1}\right) + \varepsilon_{2,t} \quad \textbf{(15)}$$

We assume that shocks to domestic money, productivity and the two commodity prices are all independent of each other. The processes for the prices foreign firms charge in their home market, world output and foreign monetary policy will also be exogenous. However, the processes underlying these three factors could in theory be linked, particularly if a Taylor rule is a good description for foreign monetary policy. For this reason we allow for the possibility of nonzero cross-diagonal elements in our initial estimation and specify them as a first order VAR:

$$\begin{pmatrix} i_t^F \\ \ln\left(P_{F,t}^F\right) \\ \ln\left(y_t\right) \end{pmatrix} = \mathrm{P} \begin{pmatrix} i_{t-1}^F \\ \ln\left(P_{F,t-1}^F\right) \\ \ln\left(y_{t-1}\right) \end{pmatrix} + \begin{pmatrix} \varepsilon_{i_f,t} \\ \varepsilon_{P_f,t} \\ \varepsilon_{y,t} \end{pmatrix} \quad \textbf{(16)}$$

2.7 Calibration

We assume that the elasticity of substitution in both markets is 6.8, the value found by Small (1997). We set the share of the 'composite good' that represents domestic goods to a value of 5%: this is equal to the United Kingdom's share of world visible exports in 2001 obtained from the *Economist Pocket World in Figures*. The parameters of the production functions in the two countries are taken from Driver (2002): both the parameter picking up the costs of substituting between commodities, η, and the elasticity of substitution, ν, are set equal to a half. Finally, labour's share, $(1-\alpha)$, is set to 0.64. The discount factor in each country is set to 0.966 implying a steady-state interest rate of 3.5% in each country. This is equal to the average ten-year spot real interest rate derived from Index-linked Gilts (IGs).

The shocks are estimated to reflect UK data, having allowed for the fact that the model has no growth and no inflation in steady state. In order to detrend our variables we use the Hodrick-Prescott filter, see Hodrick-Prescott (1997). Clearly it is important to investigate the sensitivity of our results to the detrending method used

endowment of its commodity will have no effect – which is counter intuitive – so we do not consider this shock.

and we intend to examine this in future work. For the money supply, we use HP-filtered M0. For the productivity shock, we use HP-filtered labour productivity, where this is defined as GDP (ONS Code: YBHH) divided by employees in employment (ONS Code: MGRZ).[10] For simplicity we assume that the domestic commodity is oil and use the (HP-filtered) average of the Brent Crude, West Texas Intermediate and Dubai Light Oil spot prices (Bloomberg Codes: EUCRBRDT, USCRWTIC and PGCRDUBA, respectively) as the price of domestic commodities. For the foreign commodity price, we use the (HP-filtered) 'World non-oil commodity price index' on Datastream (Code: ECALLI$).

For foreign output we use (HP-filtered) average world GDP weighted by countries' shares in total UK exports of goods and services in 1996 (Source: Datastream). For world interest rates we use a G7 (excluding United Kingdom) weighted average of three-month interbank interest rates with effective exchange rate weights applied (Source: Bank of England/BIS). In the estimated VAR, we use a demeaned version of this series.

For the producer currency pricing case we need the price of foreign goods in the foreign market and for this we use (HP-filtered) 'world export prices', where these are defined as G7 (excluding United Kingdom) weighted average of exports of goods and services deflators with effective exchange rate weights applied (Source: Datastream).[11] For the local currency pricing case, we need a series for the price of foreign goods in the domestic market. We use the (HP-filtered) UK import price deflator (ONS Code: IKBI/IKBL).

Having assembled the data, we estimate the shock processes given by equations **(12)** through **(16)**. We obtained the following results:

$$\begin{aligned} &\ln\left(M_t^D\right) = 0.68\ln\left(M_{t-1}^D\right) + \varepsilon_{M,t} \\ &\sigma_M = 0.021 \\ &\text{Sample}: 1971-2002 \end{aligned} \qquad \textbf{(17)}$$

[10] Ideally, we would like to use HP-filtered 'Total Factor Productivity', the same variable as in the model. However, since we do not have accurate annual data on commodity inputs, we chose to use labour productivity instead.

[11] An alternative choice would have been world producer prices and we intend to explore using this in future work.

$$\ln\left(A_t^D\right) = 0.49\ln\left(A_{t-1}^D\right) + \varepsilon_{A,t}$$
$$\sigma_A = 0.014 \quad \textbf{(18)}$$
$$\text{Sample: } 1971 - 2001$$

$$\ln\left(P_{1,t}\right) = \varepsilon_{P_1,t}$$
$$\sigma_{P_1} = 0.261 \quad \textbf{(19)}$$
$$\text{Sample: } 1972 - 2001$$

We found the coefficient on lagged oil prices to be insignificant in this regression.

$$\ln\left(P_{2,t}\right) = 0.56\ln\left(P_{2,t-1}\right) + \varepsilon_{P_2,t}$$
$$\sigma_{P_2} = 0.088 \quad \textbf{(20)}$$
$$\text{Sample: } 1993 - 2002$$

With respect to the VAR in foreign variables, none of the variables respond in a significant way to lagged-values of the other variables.[12] So we re-estimate the system on the assumption that the foreign variables are independent. We obtain the following results:

$$i_t^F = 0.92 i_{t-1}^F + \varepsilon_{i,t}$$
$$\sigma_i = 1.509 \quad \textbf{(21)}$$
$$\text{Sample: } 1980 - 2001$$

$$\ln\left(y_t\right) = 0.63\ln\left(y_{t-1}\right) + \varepsilon_{y,t}$$
$$\sigma_y = 0.010 \quad \textbf{(22)}$$
$$\text{Sample: } 1971 - 2001$$

$$\ln\left(P_{F,t}^F\right) = \varepsilon_{P_F^F,t}$$
$$\sigma_{P_F^F} = 0.0099 \quad \textbf{(23)}$$
$$\text{Sample: } 1992 - 2001$$

Again, we find the coefficient on lagged world export prices to be insignificant.

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[12] Of course, given the short sample for World Export Prices (1992-2001), this result is almost certainly a feature of the lack of degrees of freedom in our VAR. We intend to investigate whether we can find a longer back run of data and come back to this equation at a later date.

$$\ln\left(P^D_{F,t}\right) = 0.58\ln\left(P^D_{F,t-1}\right) + \varepsilon_{P^D_F,t}$$
$$\sigma_{P^D_F} = 0.054 \qquad \textbf{(24)}$$
$$\text{Sample}: 1971 - 2001$$

Given these shock processes, we can examine the effects of a shock to commodity prices – both the commodity produced by the domestic economy (oil) and the foreign commodity – in our small open economy model and compare these with the effects of such shocks on UK data. We can then consider the effects of changing the volatility of commodity prices on exchange rate, import price and retail price volatility.

3 The effects of a shock to commodity prices

In this section, we consider the effects of shocks to commodity prices.

Since final goods prices are pre-set, the domestic producer will face a given world demand for its output. So output will remain unchanged. But given the change in relative commodity prices, the producer will switch out of using the commodity whose price increased and into using more labour and more of the commodity whose price remained unchanged. As the domestic economy is assumed to be small this shift in the demand for the two commodities will have no impact on their world price. Given the parameterisation of our model, we find that a one percent increase in the price of a commodity will cause domestic demand for that commodity to be reduced by 1.5% and demand for the other commodity to be increased by 0.5%. The demand for labour goes up by 0.28%.

After the initial period, producers are able to change their prices. If the shock to commodity prices persists, in either case, domestic producers will raise prices in line with the increase in their costs. Since we are assuming that foreign producer prices are exogenous – recall we found lagged commodity prices to have no effect on current world export prices in the data – this means that the relative price of domestic goods will have increased. So demand for domestic goods and, hence, domestic output will fall. Since demand has fallen, firms will cut back on their demand for labour and both commodities, more for the commodity whose price has risen. With lower wages and lower dividends, consumers will reduce consumption.[13]

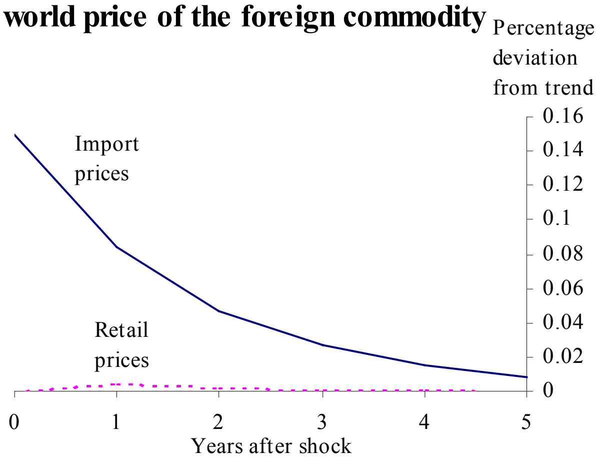
[13] To obtain this result, we look at a calibration of the model in which shocks to the world price of the domestic commodity are persistent. Recall that in our baseline calibration such shocks are completely transitory, which would imply that such shocks would have no effect except in the period of the shock itself. In this case, we simply find a one-period rise in labour demand and domestic demand for the foreign commodity and a one-period fall in domestic demand for the domestic commodity.

Neither shock has any effect on the nominal exchange rate. This follows from our assumptions about domestic and foreign monetary policy. Since the domestic money supply is held constant, the exactly offsetting movements in domestic consumption and the domestic price level imply unchanged domestic nominal interest rates. Foreign nominal interest rates are assumed not to respond to movements in commodity prices, a result we found in the data. So, with neither domestic nor foreign nominal interest rates moving, the exchange rate will not move.

Indeed, the only shocks that will have any effect on the nominal exchange rate in this model are domestic or foreign monetary policy shocks. This implies that all exchange rate volatility arises from volatility in domestic and foreign monetary policy. To the extent that shocks to commodity prices affect domestic import and retail prices, then their presence will lead to a disconnect between the exchange rate and import and retail prices. We investigate this further in the next section.

The effect on import prices depends on the commodity whose price has changed. Since oil is exported and a shock to the price of oil has no effect on the domestic price of foreign goods, an oil price shock will have no effect on import prices. A shock to the world price of the foreign commodity will have no effect on the domestic price of foreign goods but will have a direct effect on import prices, since its price is part of the index. Driver (2002) suggests that commodities have formed about 15% of UK imports over the 1990s. This implies that the effect of a one per cent rise in the world price of the foreign commodity will be to raise import prices by 0.15%. This rise in import prices will persist as long as the shock to the price of the commodity.

Chart 2. Effect of a 1% rise in the world price of the foreign commodity



Finally, we can note that commodity price shocks are going to have the same effect whether or not producers are pricing in local currency or in their own currency. This is because movements in commodity prices affect their costs and they would aim to pass this cost increase on to consumers both at home and abroad. Since changes in commodity prices will not affect relative demand, there will be no incentive to pass on the cost increase to a different extent in different markets.

These results are reflected in the impulse response functions plotted in chart 2, below. We first note, again, that a shock to the world price of the domestic commodity will have no effect on the exchange rate, import prices or consumer prices given our calibration since it is assumed to be entirely transitory. In chart 2, we plot the effects of a shock to the world price of the foreign commodity on import prices and retail prices noting that the shock will have no effect on the exchange rate.

4 The effects of commodity price volatility

In this section, we examine the effects of commodity price volatility on the volatility of the exchange rate, import prices and retail prices. We do this by calculating the asymptotic variances of the exchange rate, import prices and retail prices with each of our pricing assumptions and with the shocks to commodity prices switched on and off. To compute the asymptotic variances, we used a variant of the Hansen and Sargent (1998) doubling algorithm also used by Batini, Harrison and Millard (2001) and Williams (1999). The results are reported in table A, below.

Table A: Effects of volatile commodity prices on exchange rate, import price and retail price volatility

	Commodity price volatility	Exchange rate volatility	Import price volatility	Retail price volatility
Producer currency pricing	Off	0.2316	0.7000	0.2159
	On	0.2316	0.7002	0.2159
Local currency pricing	Off	0.2316	0.1343	0.0040
	On	0.2316	0.1344	0.0040

The table shows, as expected, that under producer currency pricing both import and retail price volatility is considerably higher than under the local currency pricing alternatives. In each case the volatility of import prices is higher than that of retail prices because the impact of exchange rate changes on the domestic currency price of the commodity will be one-for-one.

In section 3 we show that commodity price shocks have the same effect whether or not producers are pricing in local currency or in their own currency. Movements in commodity prices will affect firms' costs and, since changes in commodity prices will not affect relative demand, they would aim to pass this cost increase equally on to consumers both at home and abroad. However, commodity price increases will only be passed onto the consumer in the form of higher retail prices in the case where there are not transitory. Since shocks to commodity prices have such small effects on retail prices, retail price volatility is unaffected by commodity price volatility. In addition, our assumptions about monetary policy at home and abroad imply that volatility in the exchange rate is unaffected by volatility in commodity prices. Therefore only import price volatility will increase with a rise in commodity price volatility since commodity prices form part of import prices.

The result that commodity price volatility has little impact on the volatility of exchange rates or retail prices backs up the data shown in chart 1. This is particularly evident over the most recent past when the volatility of oil prices has been increasing. Over the same period the volatility of the exchange rate has, if anything, been falling and that of retail prices not changing. However, commodity price volatility does have an impact on import price volatility and this is particularly evident in the early part of the sample. So, an increase in commodity price volatility might be associated with a greater 'disconnect' between movements in import prices and movements in the exchange rate.

5 Implications for monetary policy

In this section, we look at whether or not monetary policy should respond to commodity price movements and whether the answer to this question depends on the persistence and volatility of such shocks. We can get a handle on this question by examining the impulse response functions presented in section 3, above. Monetary policy makers will only respond to shocks that effect the variables they are interested in. Suppose the goal of the monetary authority is to minimise a loss function including the volatility of output and inflation. Given one-period price stickiness, a purely temporary shock (that is, a 'white noise' shock) to the price of either commodity will lead to no monetary policy response since output and inflation will be unaffected by the shock. This will happen under both pricing schemes. Interestingly enough, this result suggests that there should be no monetary policy response to shocks to the price of oil since our empirical results suggested that this series followed a white noise process. For temporary shocks, therefore, the choice of the specification of monetary policy in section 2.5, with monetary policy makers simply aiming to control the money stock, will not have an impact on our results.

For more persistent shocks, however, the choice of monetary policy will be important. If, instead of aiming to control the money supply, the monetary authorities follow a

Taylor rule they would want to respond to more persistent shocks as these will have an impact on output and inflation. Once monetary policy reacted to such shocks then the exchange rate would also move. The results in the previous sections and in particular the lack of feedback from commodity price volatility to exchange rate volatility are therefore partly driven by the form of monetary policy rule which we have chosen. The result of this discussion is that we only need consider how, if at all, monetary policy should respond to persistent shocks to commodities.

In what follows, we consider the optimal monetary policy response to a persistent shock to the price of the foreign commodity. When doing this, we switch off the shocks to our other exogenous variables.[14] We postulate a monetary policy decision rule of the form:

$$\ln(M_t) = \sum_{j=0}^{J} \beta_{1,j} P_{D,t-j} + \beta_{2,j} P_{F,t-j} + \beta_{3,j} P_{2,t-j} \qquad \textbf{(24)}$$

That is, the domestic monetary authority sets the money supply based on a distributed lag of the shock to the price of the foreign commodity as well as the two predetermined prices. Given our model, we choose the coefficients of this decision rule so as to minimise the loss function:

$$L = Var(4\Delta \ln(P_t)) + Var(\ln(y_t)) \qquad \textbf{(25)}$$

This loss function is standard: the monetary authority dislikes volatility in the annualised rate of inflation and in output.

[To be completed]

6 Conclusions

In this paper we look at the effects of shocks to commodity prices in a small open economy. We find that, when monetary policy aims simply to control the money stock, shocks to commodity prices on their own have no effect on the exchange rate and only a negligible effect on the retail price index operating through firms' costs. Having examined the effects of commodity price shocks, we then look at the impact of commodity price volatility on the volatility of the exchange rate, import prices and retail prices. We find that introducing shocks to the prices of the two commodities has a negligible effect on the volatility of the exchange rate or retail prices. This is

[14] This is to keep the exposition simple. We can do this without loss of generality since we have assumed that all shocks are uncorrelated with each other.

true whether or not producers price in their own or local currency. This suggests that finding for a link between commodities and exchange rates will depend on two possible scenarios. The first of these is a scenario in which shocks to commodity prices are persistent and policy makers are interested in targeting output and inflation. The second scenario is one where a particular country has market power in the commodity that they export.

The results are consistent with recent data showing more volatile commodity prices and less inflation and exchange rate. Commodity price volatility does, however, have an impact on import price volatility and therefore an increase in commodity price volatility might be associated with a greater 'disconnect' between movements in import prices and movements in the exchange rate.

We suggest that monetary policy makers will not wish to respond to a purely temporary shock (that is, a 'white noise' shock) to the price of either commodity. Given that oil prices appear to have followed a white noise process over the past three decades, this suggests that monetary policy makers should not respond to oil price movements. Of course, this result assumes that inflation expectations are 'anchored'. If a rise in commodity prices lead to a rise in inflation expectations, then the monetary authority may wish to respond, even if the shock is purely white noise.

There are many avenues down which this research could be taken further. In terms of the model, we can consider more realistic forms of price stickiness and other nominal rigidities and examine the impact of commodity price shocks in these more realistic settings. We could make nominal interest rates the instrument of monetary policy in the economies we consider and then examine what our model has to say about simple monetary policy rules. It may be that a rule in which the monetary authority sets its policy rate as a function of commodity prices in addition to output and inflation performs better than a Taylor rule regardless of its optimality properties. Finally, we could examine the extent to which commodity price movements may have effects on volatility via their effects on expectations. Much discussion about the poor monetary policy performance of the 1970s is based around this kind of mechanism.

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